Automated Spacecraft Scheduling

The ASTER Example

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The Concept

- Scheduling by software instead of humans
- Ideally suited to orbital observing missions
- Rationale:
  - Increased target data return
  - Lower cost
- Now operating on ASTER / Terra (EOS-AM1)

Some Targeting Options for Earth Observing Missions

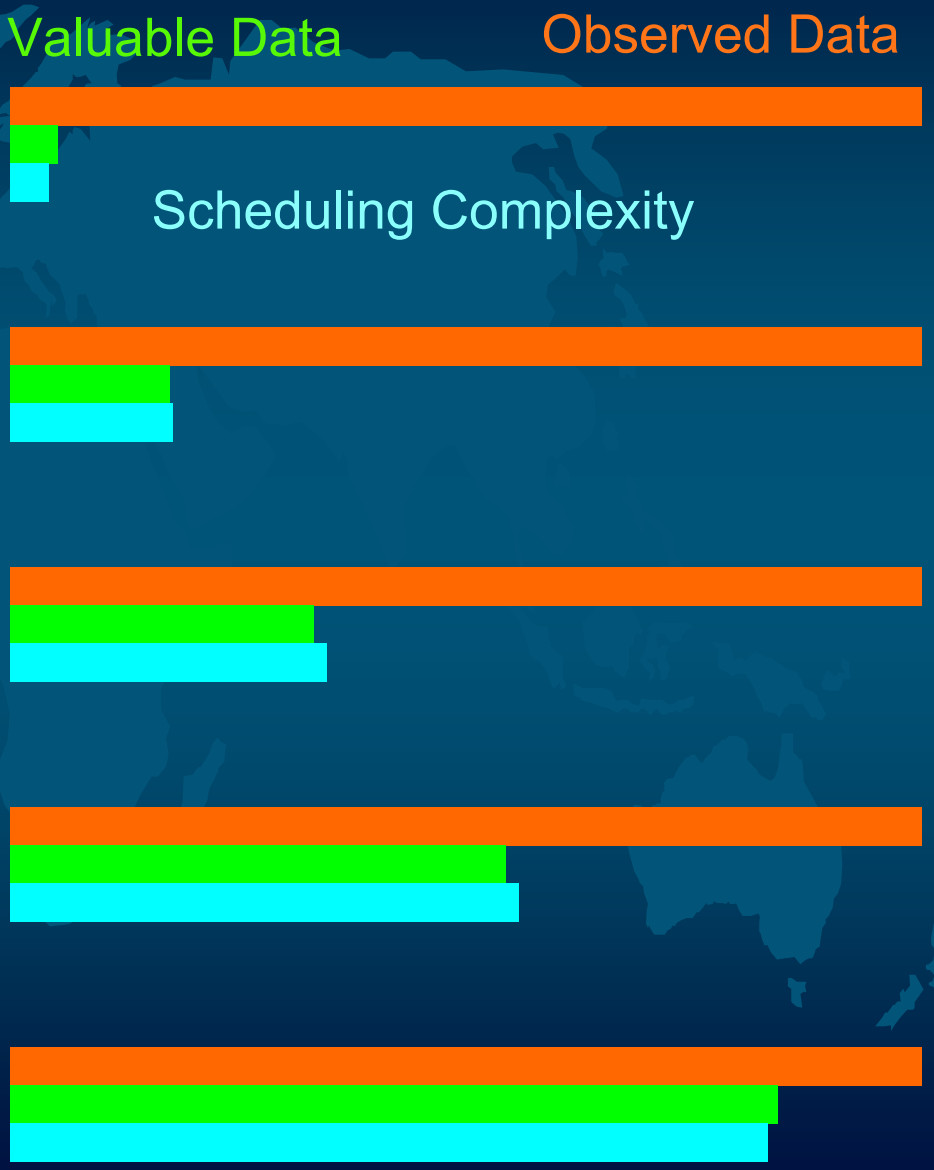
Observe Everything

Observe Land Mass Only

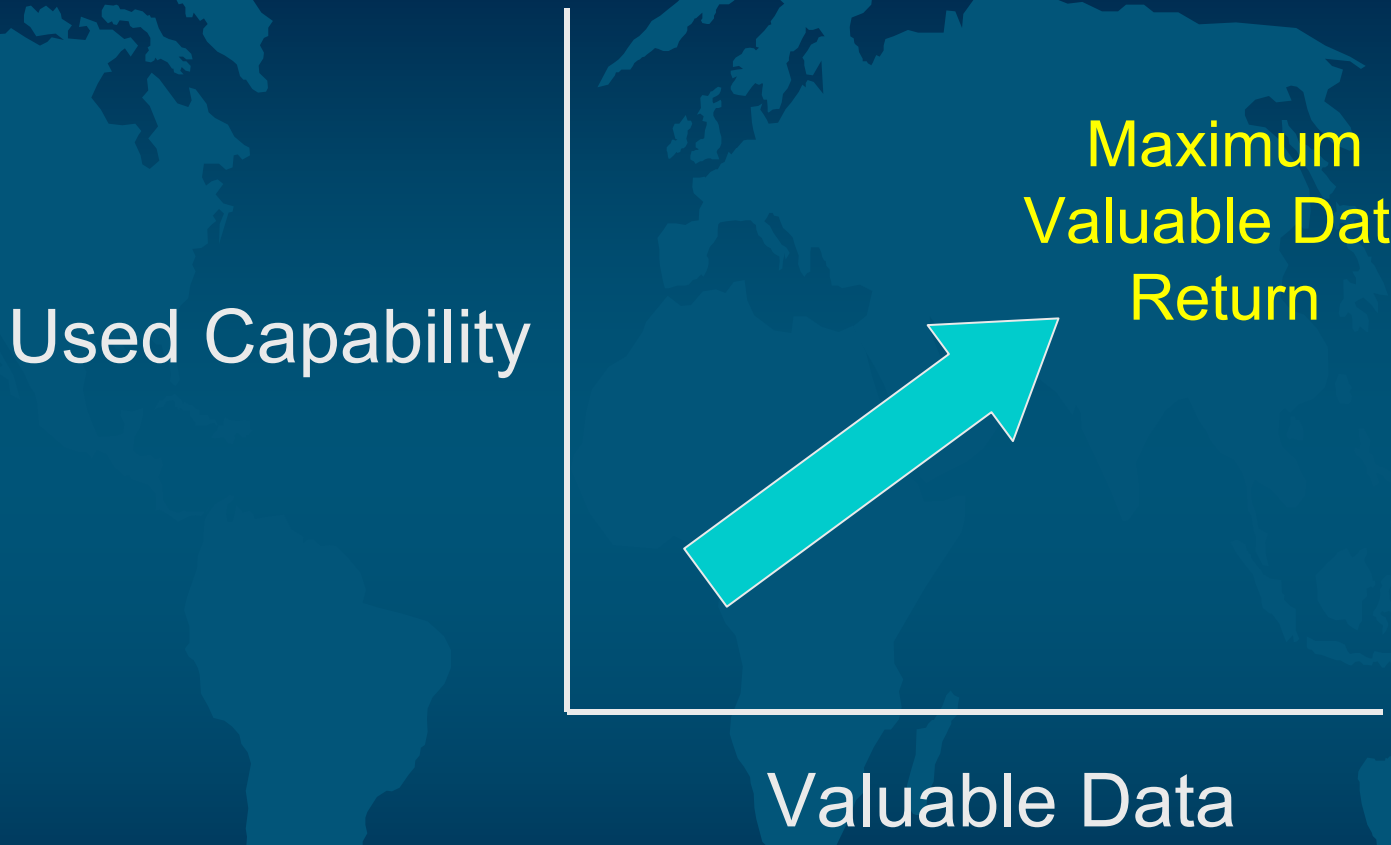
Observe Targets Only

Emphasize High Priority Targets

Emphasize High Priority Cloud-Free Targets



Maximum Performance



Maximize: $\frac{\text{Used Capability}}{\text{Total Capability}}$ and $\frac{\text{Valuable Data}}{\text{Observed Data}}$

Conventional Human Scheduling

- Select high priority targets
- Check the weather report
  - Avoid clouds
- Calculate observation times, pointing angles, etc.
  - Software tools
  - Groundtrack grid charts
- Generate command sequences
- Check constraints
  - OR always stay well within limits

Questions…

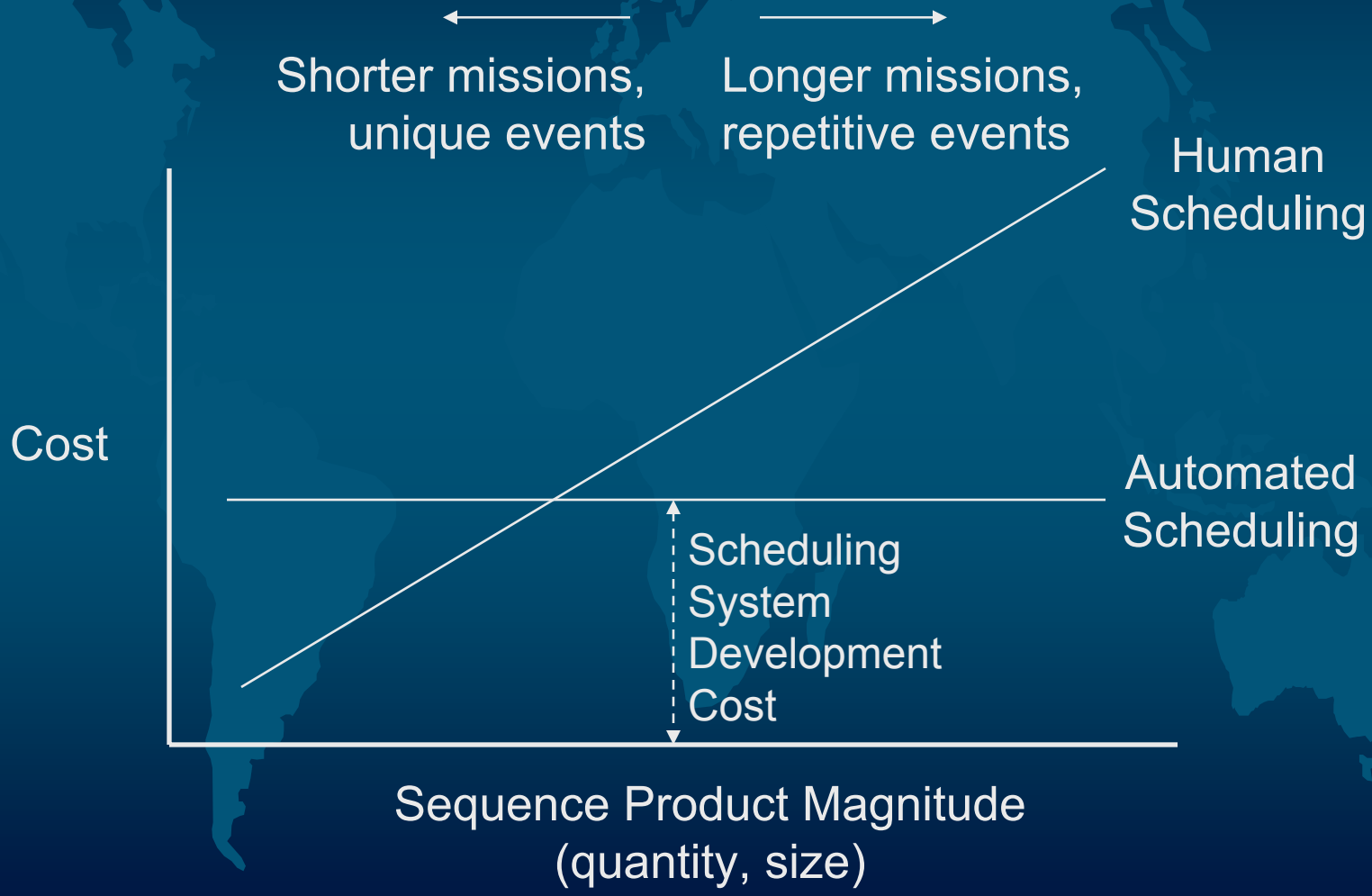
- What is the workforce cost of manually creating schedules?
- What is the workforce cost of adjudicating between competing requesters? *(and career cost?)*
- What about all that “slack” time?

- Are we fully utilizing spacecraft capability?
  - Manually optimizing schedules is expensive
  - Cassini sequences require work-years

Automated Scheduling

- Automatic:
  - Target prioritization
  - Schedule creation
  - Constraint checking
- Humans are elevated to a higher level
  - Humans set goals, software handles the details
  - Can still “joystick” the spacecraft
    - Input desired activity with high priority
- Compared to conventional scheduling:
  - More optimal (maximizes capability used and valuable data)
  - Faster
  - Lower cost
  - Safer

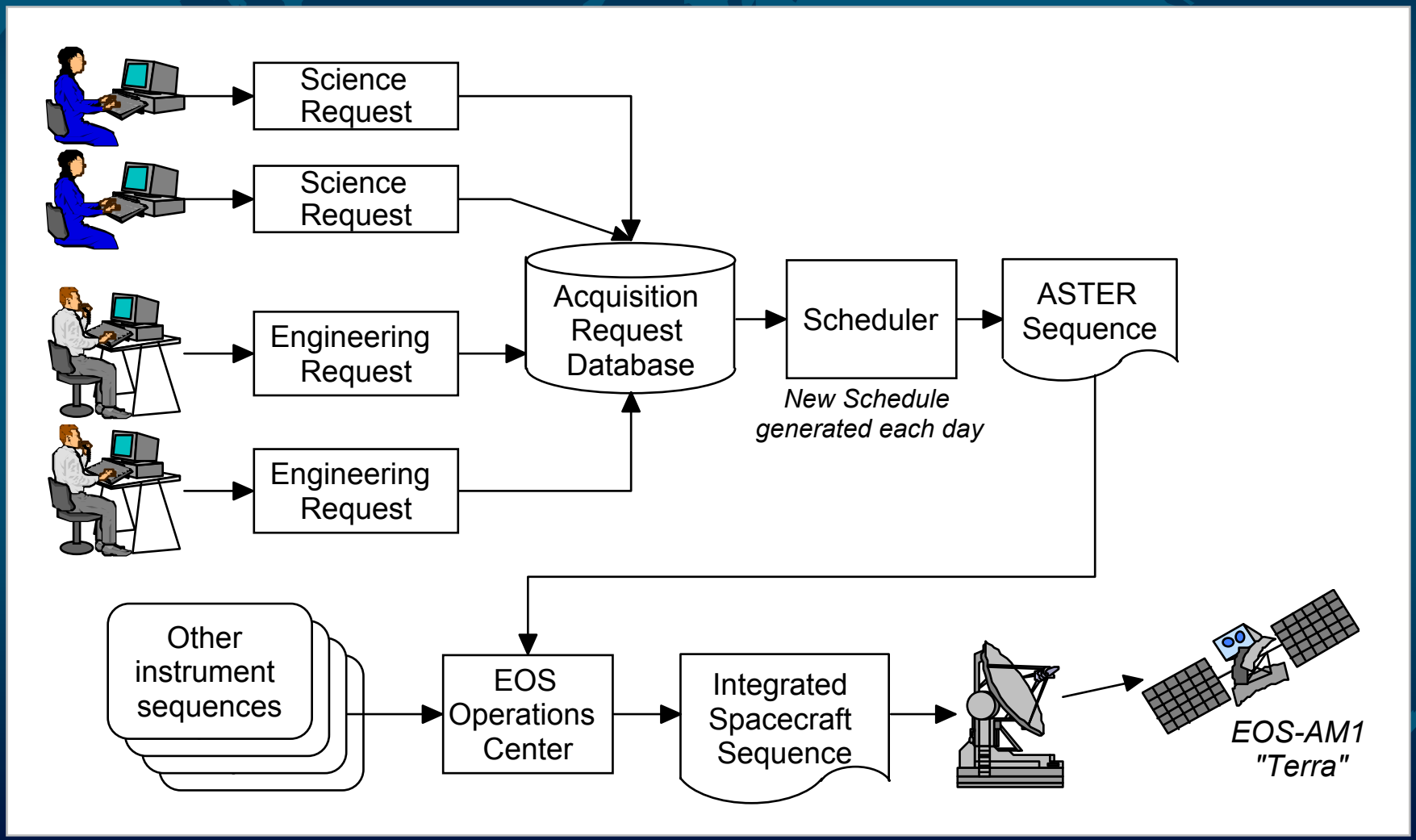
When is Automated Scheduling Appropriate?



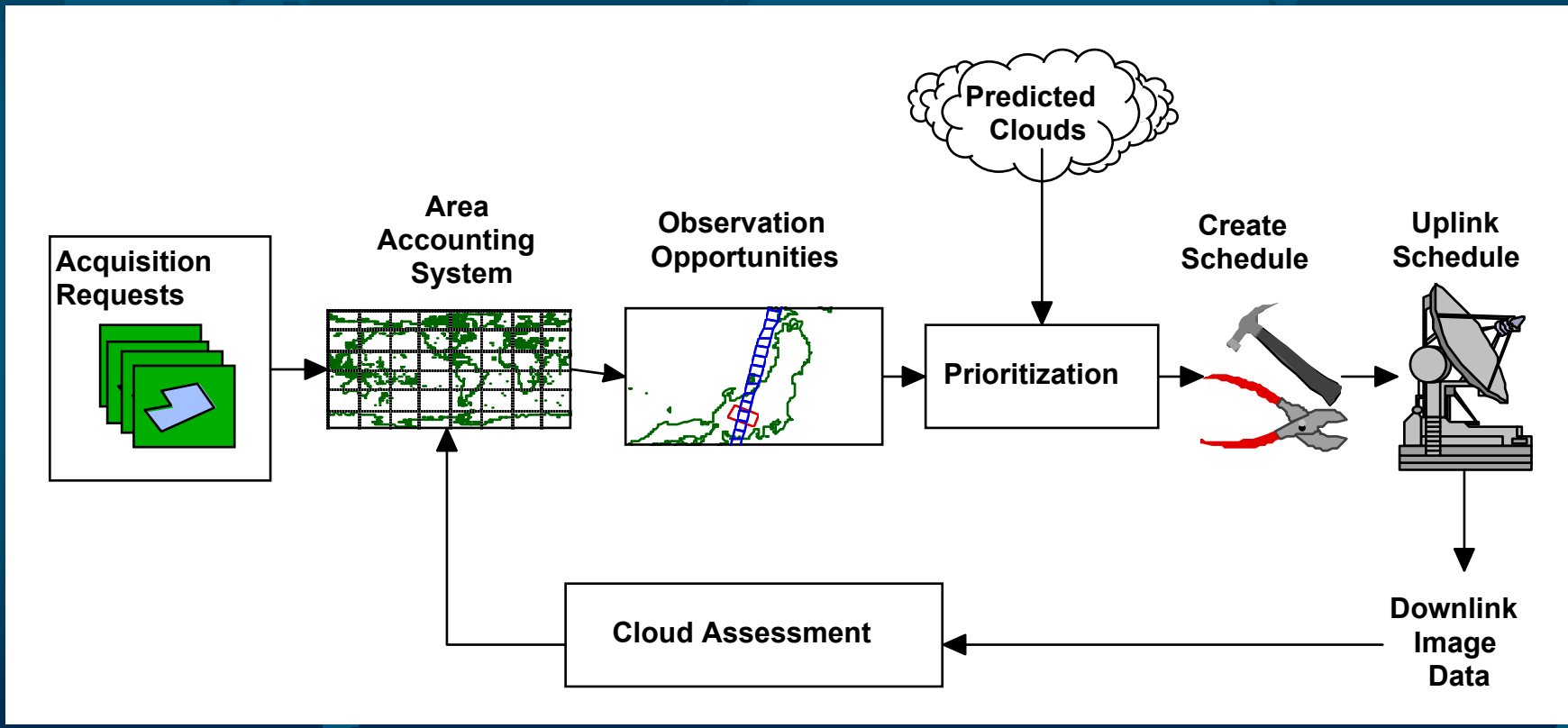
The ASTER Example

- Advanced Spaceborne Thermal Emission and Reflection Radiometer
- Built by Japan MITI/JAROS
- Currently operating on NASA Terra (EOS-AM1)
- Multiple telescopes, visual through thermal infrared
- Polar orbit, 16-day groundtrack repeat cycle
- Crosstrack pointing +/- 24 deg
- 60 km observation swath
- 10 m resolution in visible channels
- Many observation modes and settings
- Observations highly constrained by data, power, and thermal limits
- Many competing users

ASTER Uplink Process

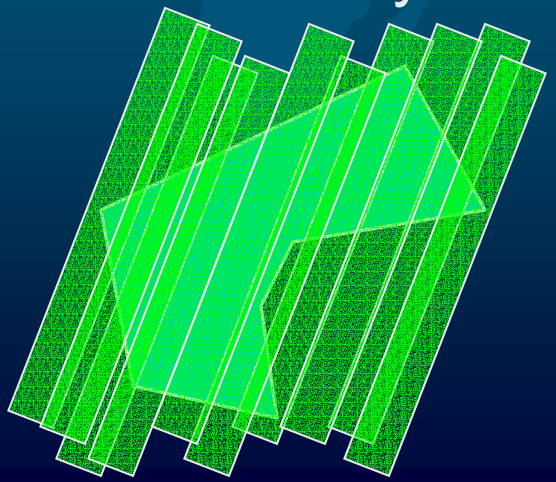


ASTER Scheduling Process



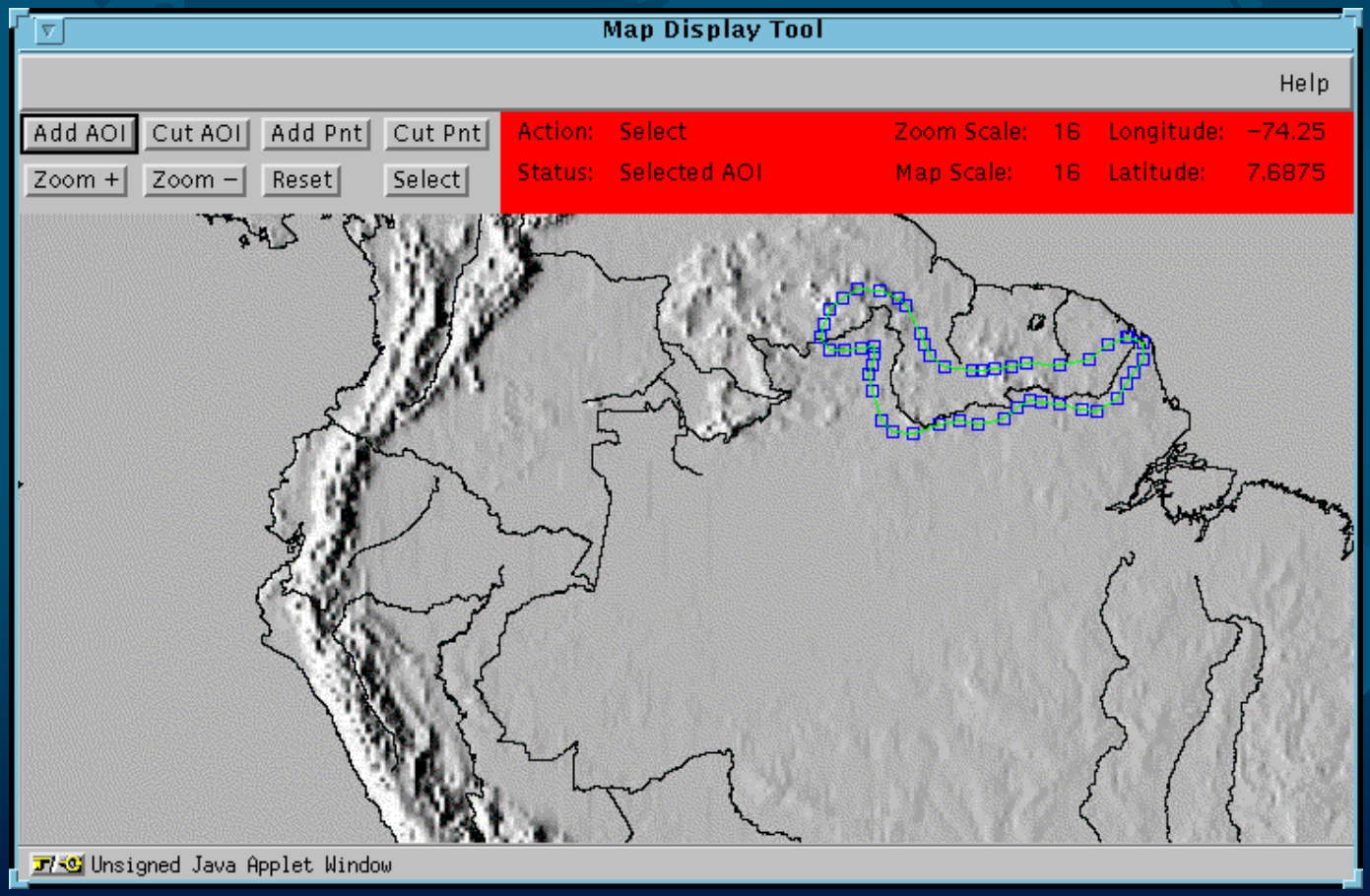
ASTER Acquisition Requests

- User specifies:
  - Polygonal target Area of Interest (AOI)
  - Instrument mode & settings
  - Requirements on timing, lighting, repeat obs, etc.
- Request is fulfilled over time
  - Generally multiple observations
  - AOI can be much larger than observation swath
  - Cloudy areas automatically reobserved



ASTER Acquisition Requests (xARs)

Area of Interest



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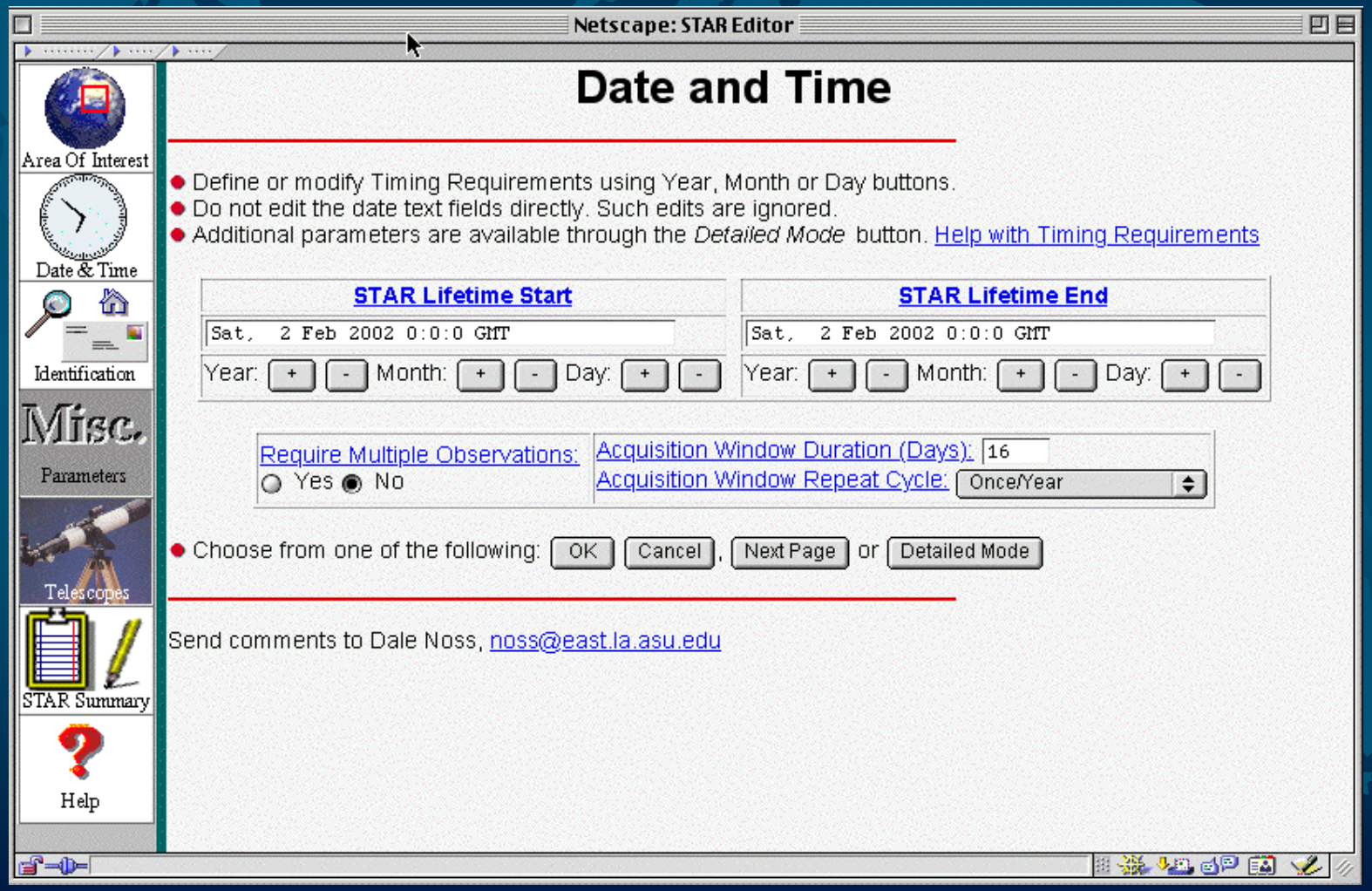

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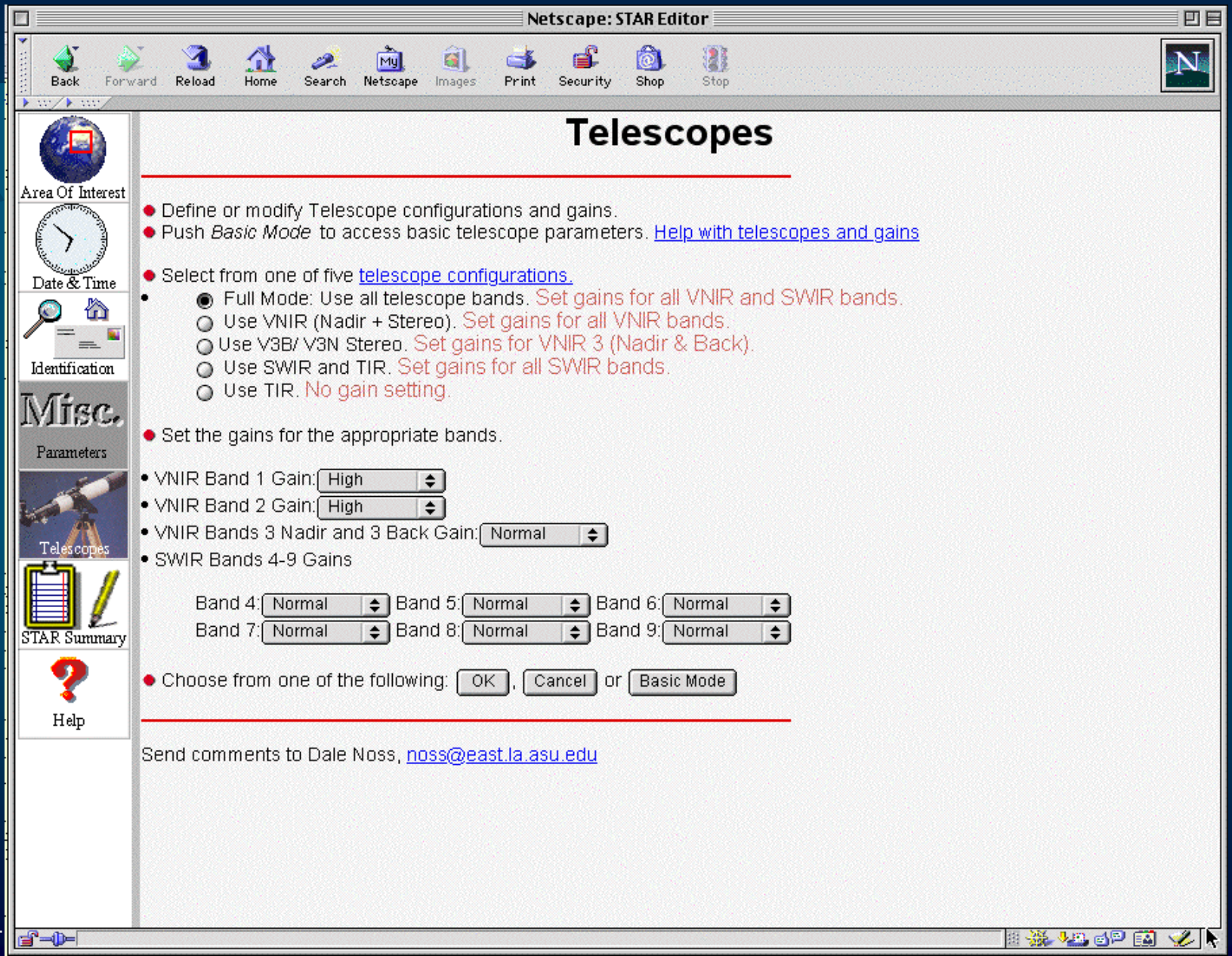

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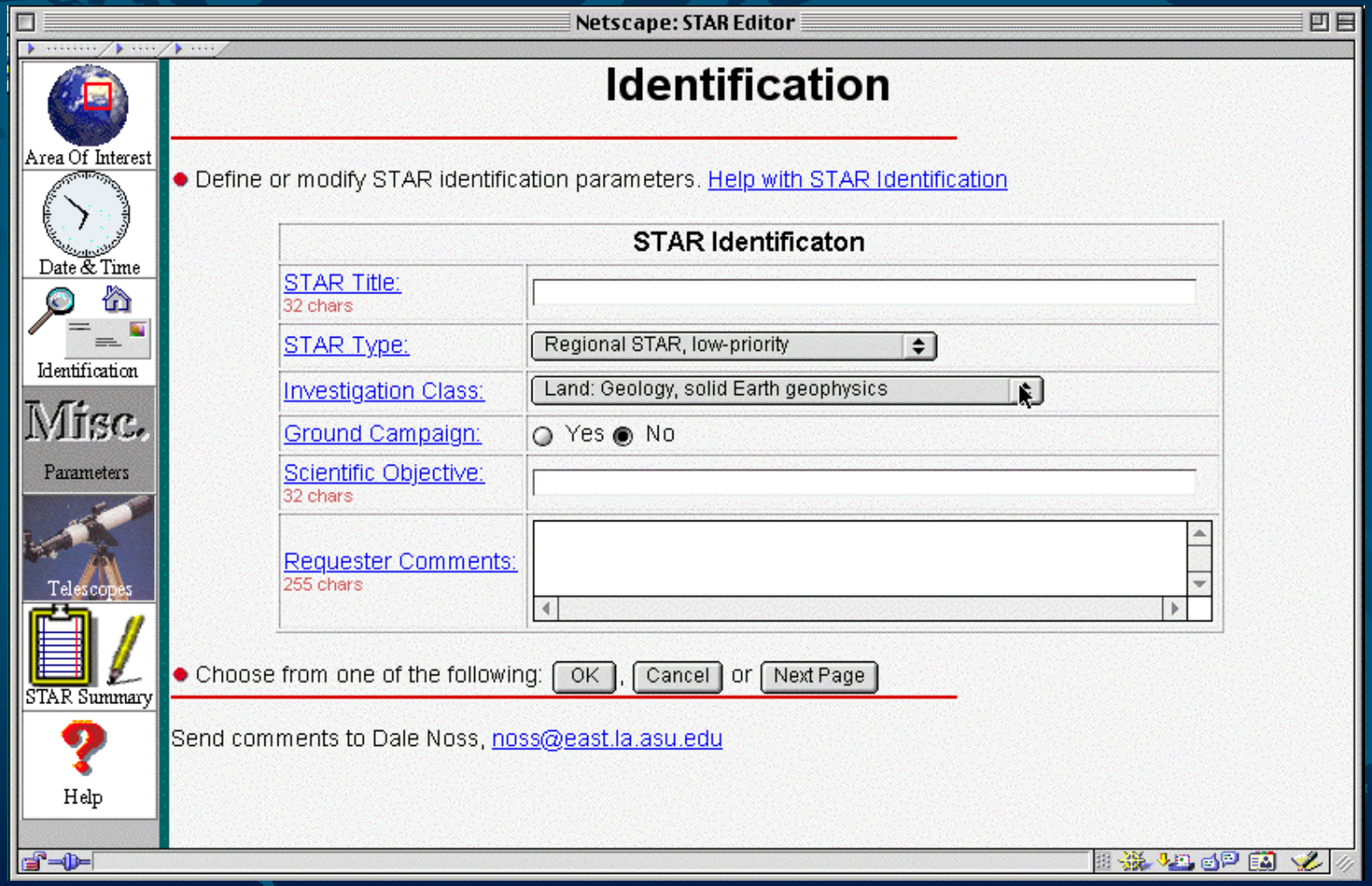

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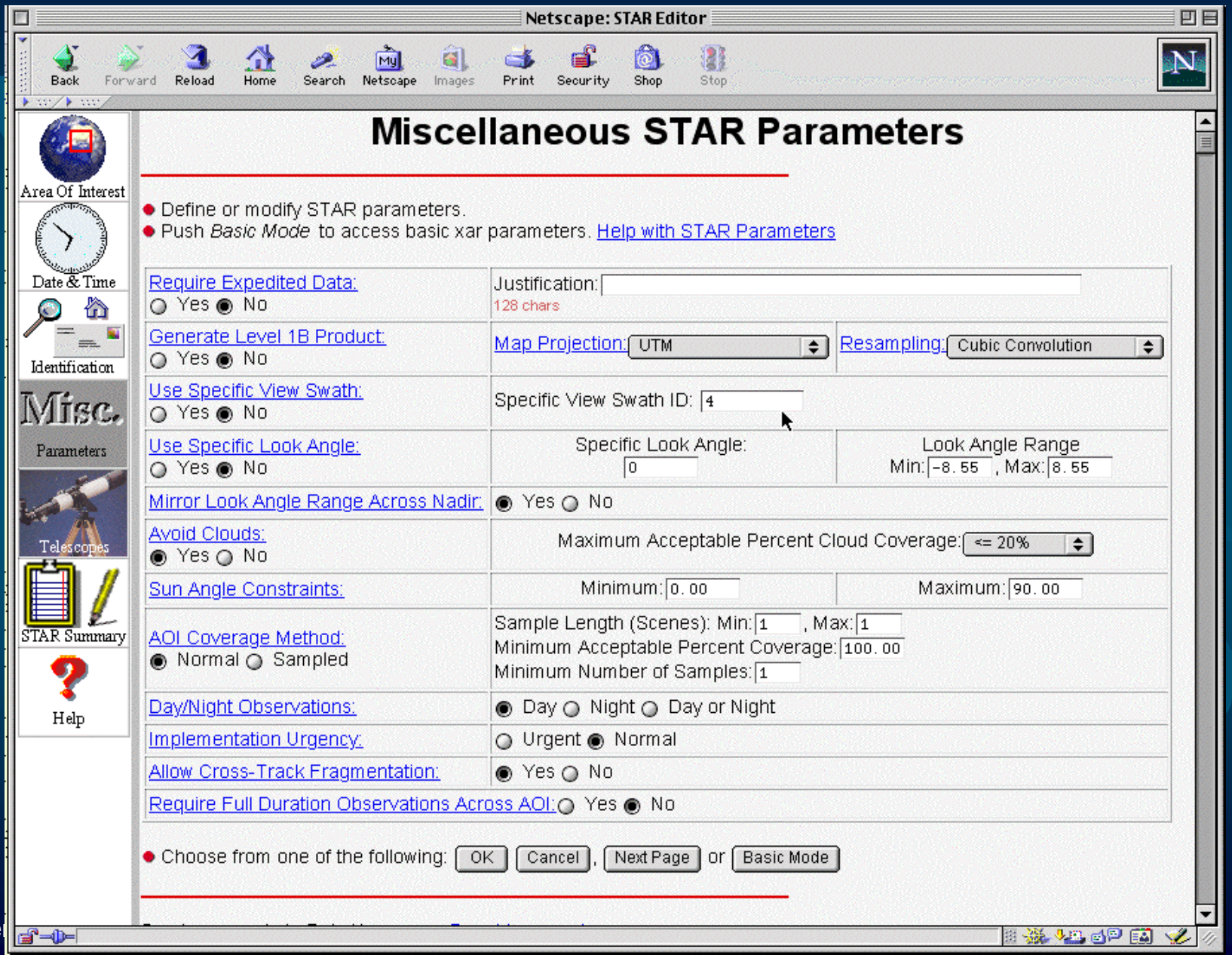
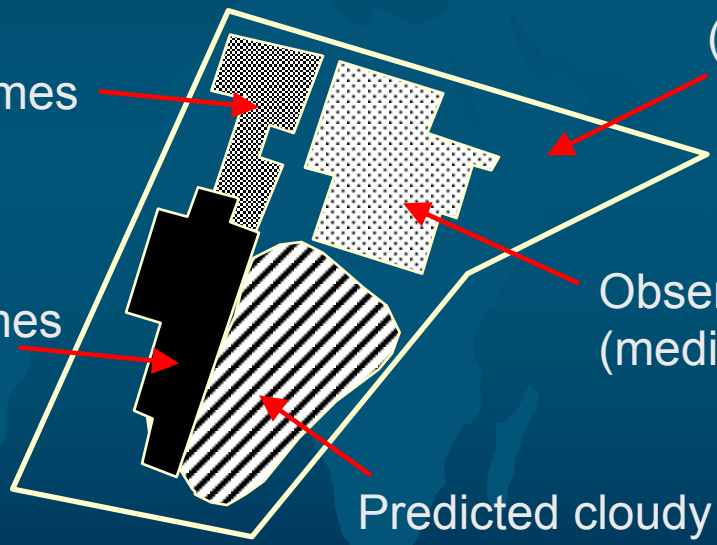


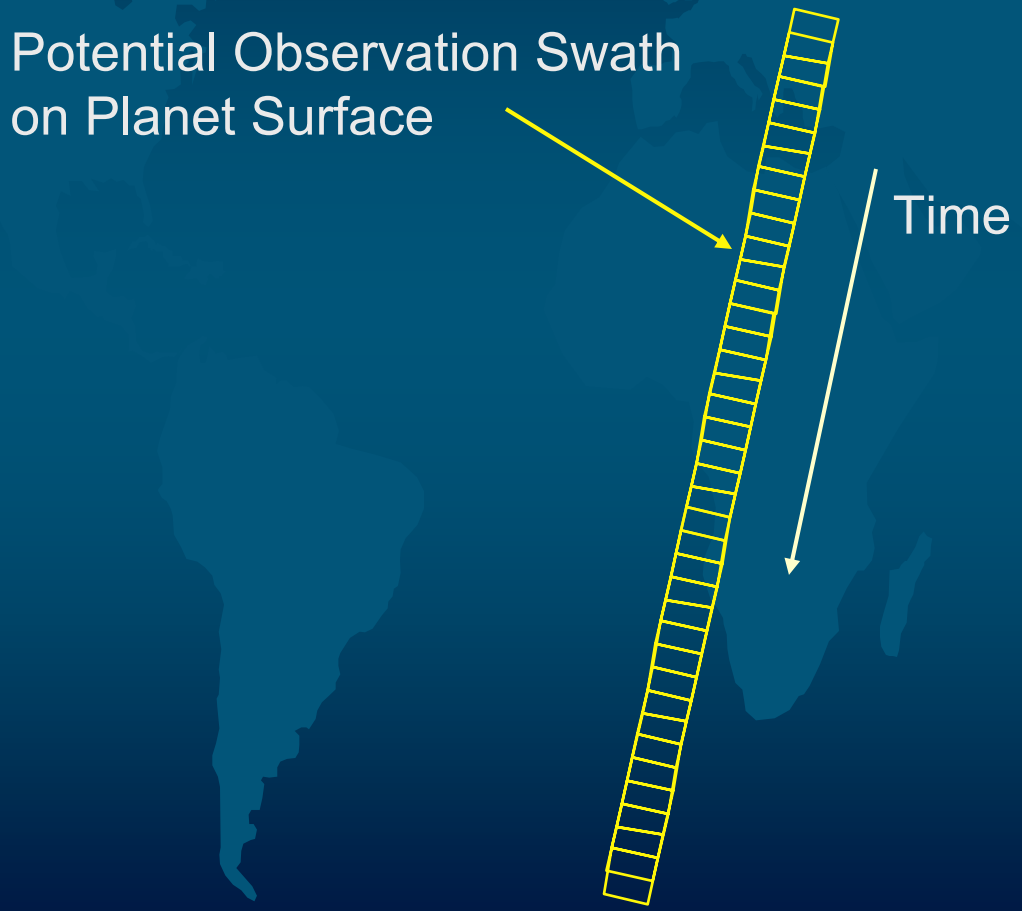
Prioritization: Priority Varies With Position, Time, Cloudiness, Etc.

Example: 3 repeat observations requested



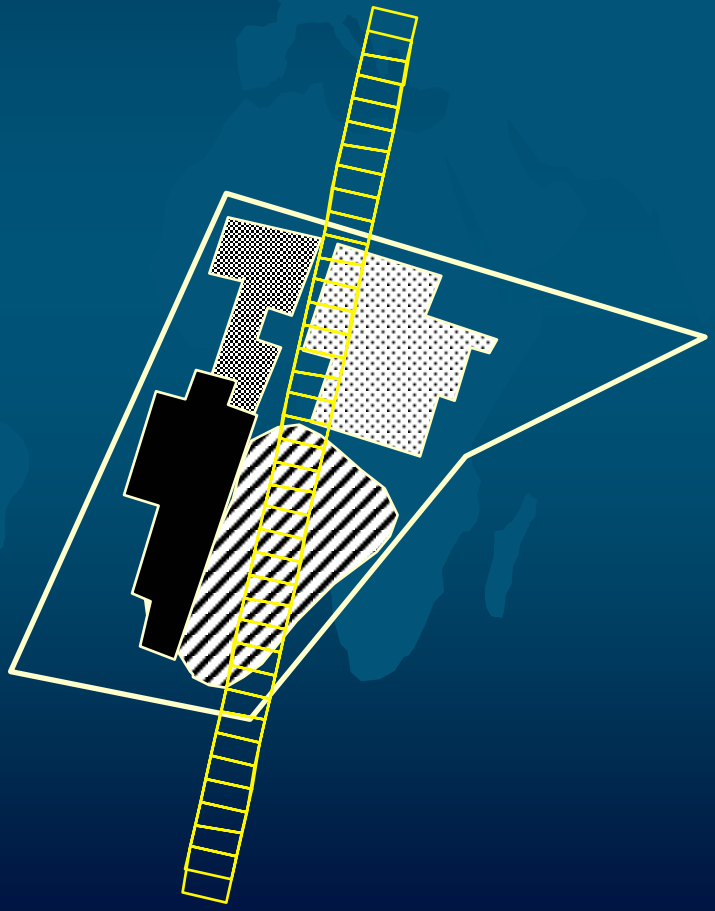
Data maintained globally in 1 km^2 pixels in GIS

Prioritization: Observation Swaths



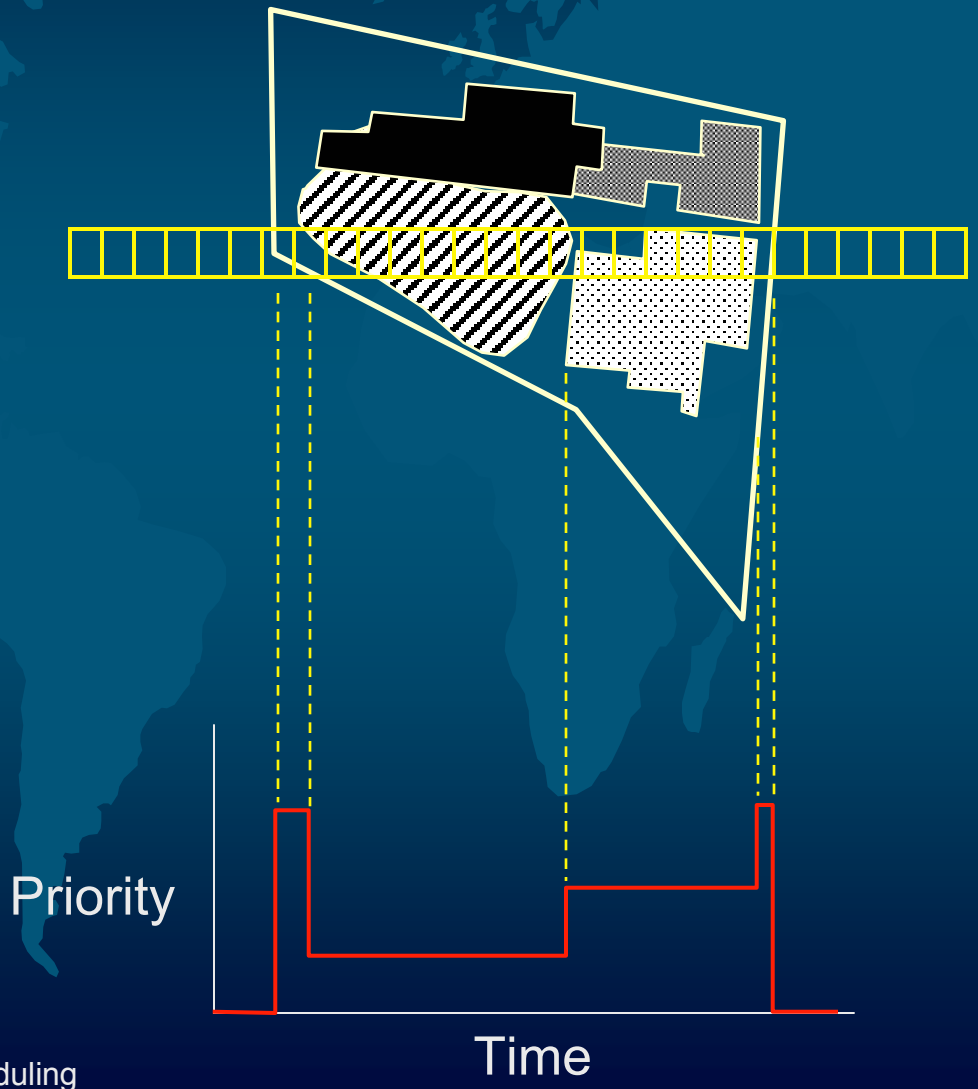
Prioritization Process

Overlay potential observation swath onto planet surface:



Prioritization Process

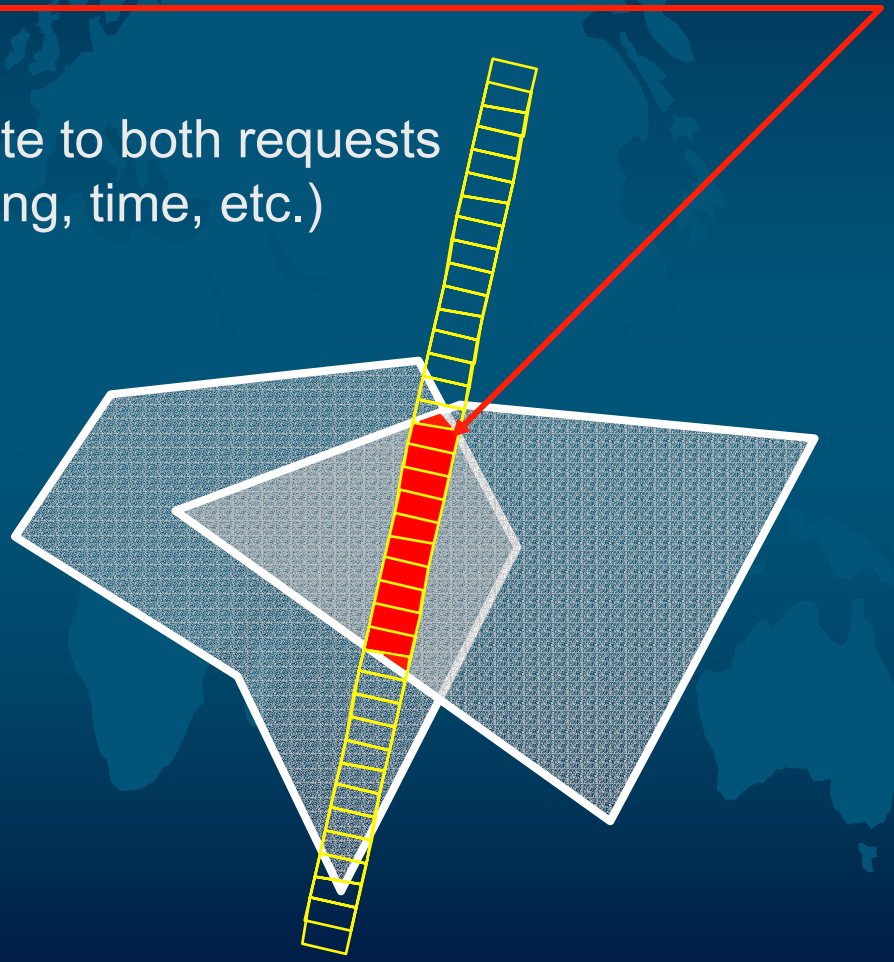
Calculate priority of areas under swath:



Priority of Requests is Additive

Priority = Priority 1 + Priority 2

IF single observation can contribute to both requests
(common constraints: mode, lighting, time, etc.)

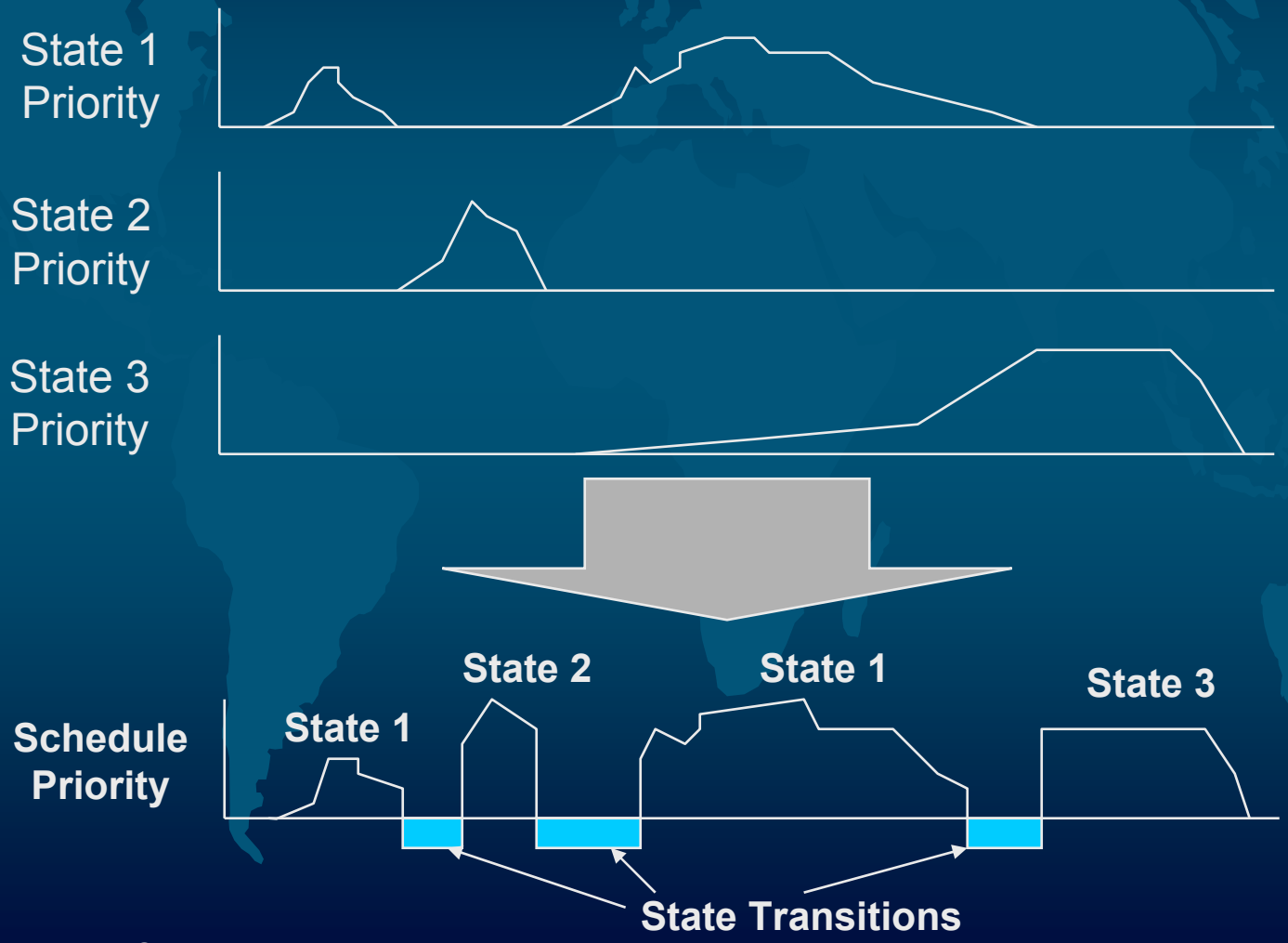


Scheduling Algorithm Approach

1. Create curves of priority vs. time for each potential spacecraft state

Scheduling Algorithm Approach

2. Create schedule with maximum integral priority



ASTER Priority Function

Prioriity of a point on the Earth's surface:

$$\text{Priority} = f_0 + (f_1 \times f_2 \times \text{L} \times f_{11})$$

Prioriity adjustment factor for "joysticking"

ASTER Priority Function Terms

- Data Collection Category
  - Engineering, Science, Individual, etc.
- Ground Campaign
- User Category
- Cloudiness
  - Predicted cloudiness, at observation time, vs. users's cloud limit
- Urgency
- $$\frac{\text{Remaining Revisits}}{\text{Remaining Observation Opportunities}}$$
- $$\frac{\text{Remaining Area}}{\text{Requested Area}}$$
- Time Since xAR Submission
- Pointing Control
  - If above desired pointing usage curve, downweight observations that request pointing changes

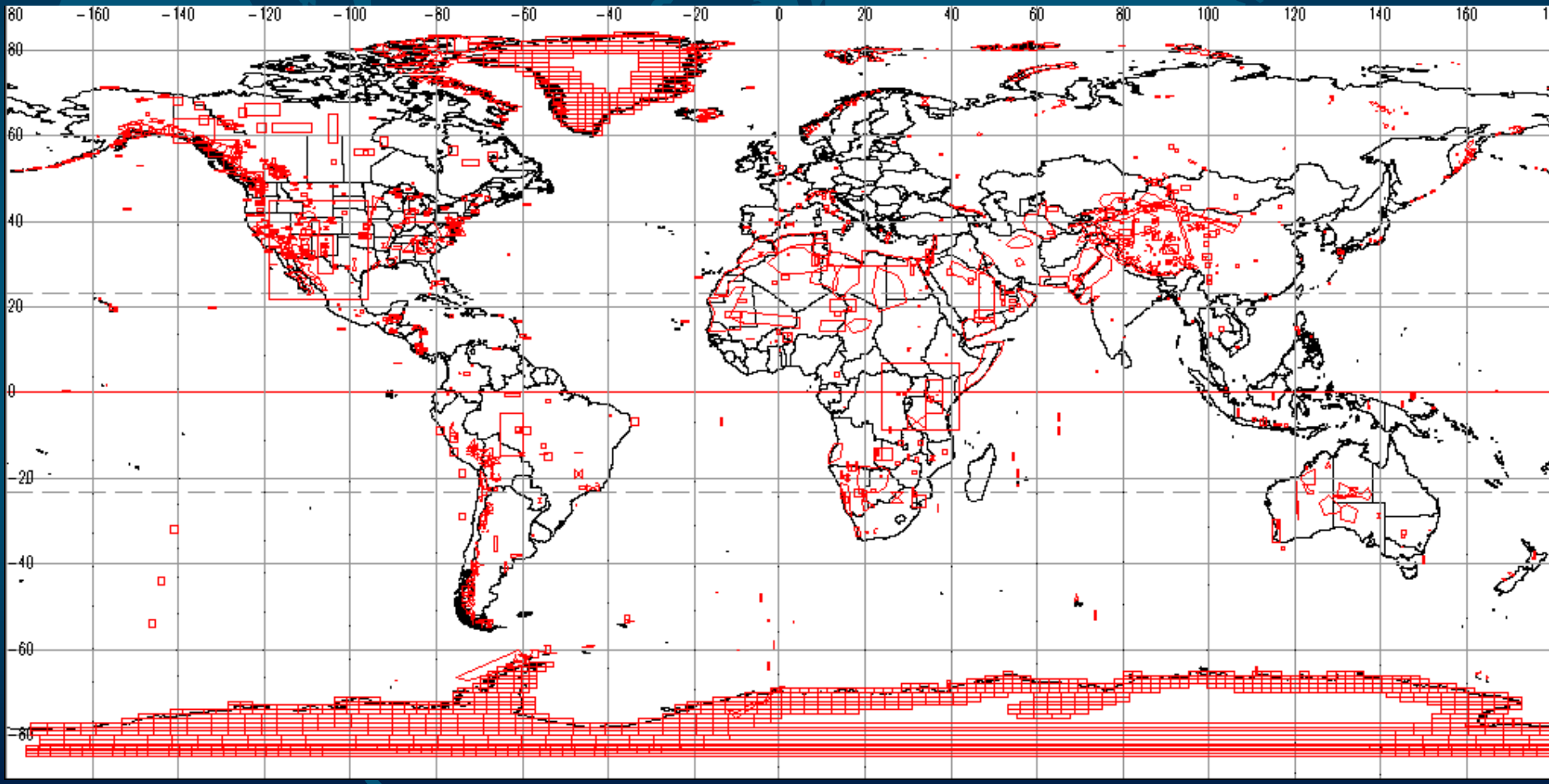
2 ASTER Scheduling Systems

- Independent developments
- ASTER Ground Data System Scheduler in Tokyo
  - Generates ASTER schedule once per day
  - Based on JPL algorithm
- ASTER Mission Simulator (AMS) at JPL
  - Second generation system
  - Intended for mission planning

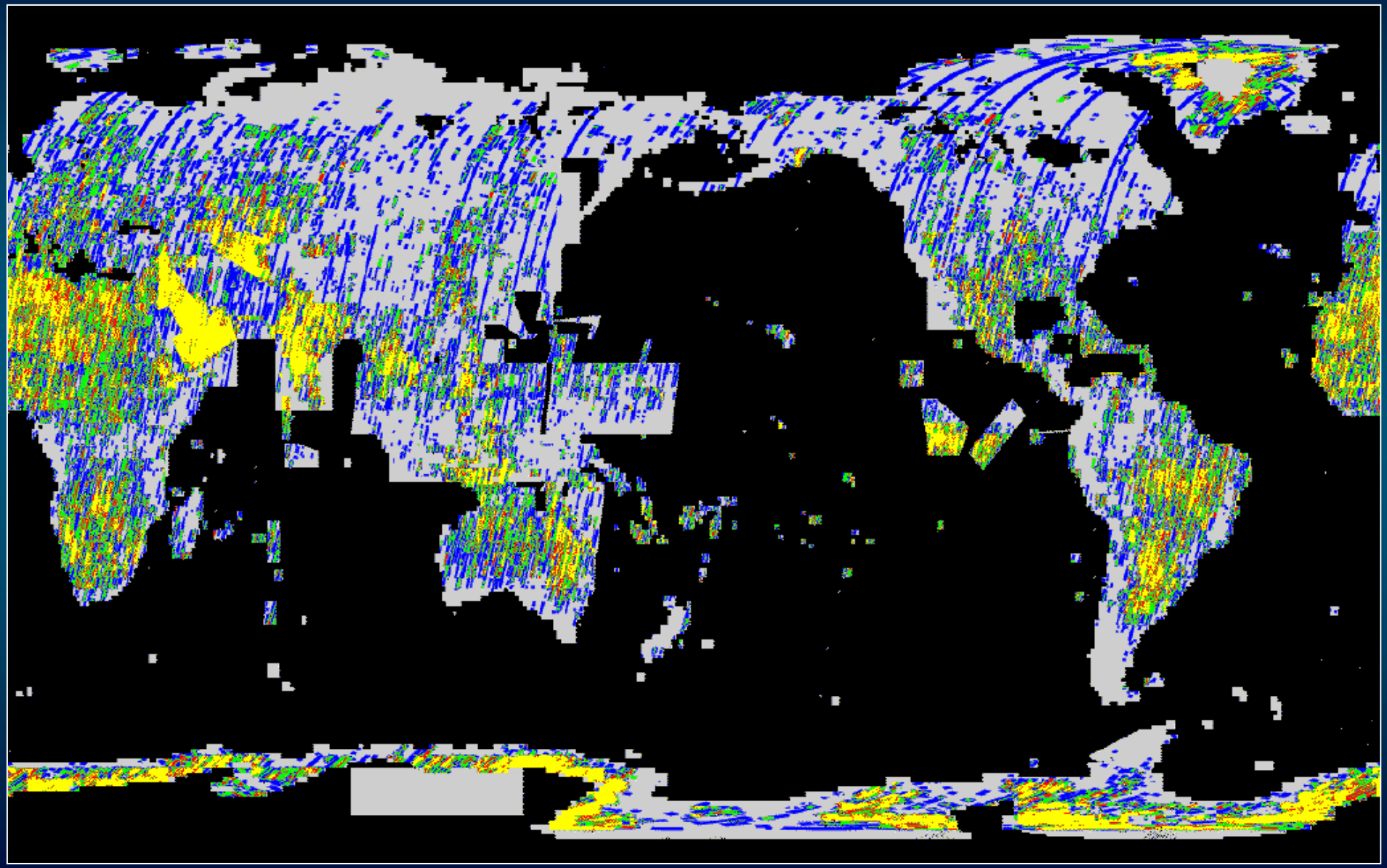
- Generates schedules
- Simulates clouds
- Performs observations and cloud assessment
- Tracks successful and failed observations

Mission simulations

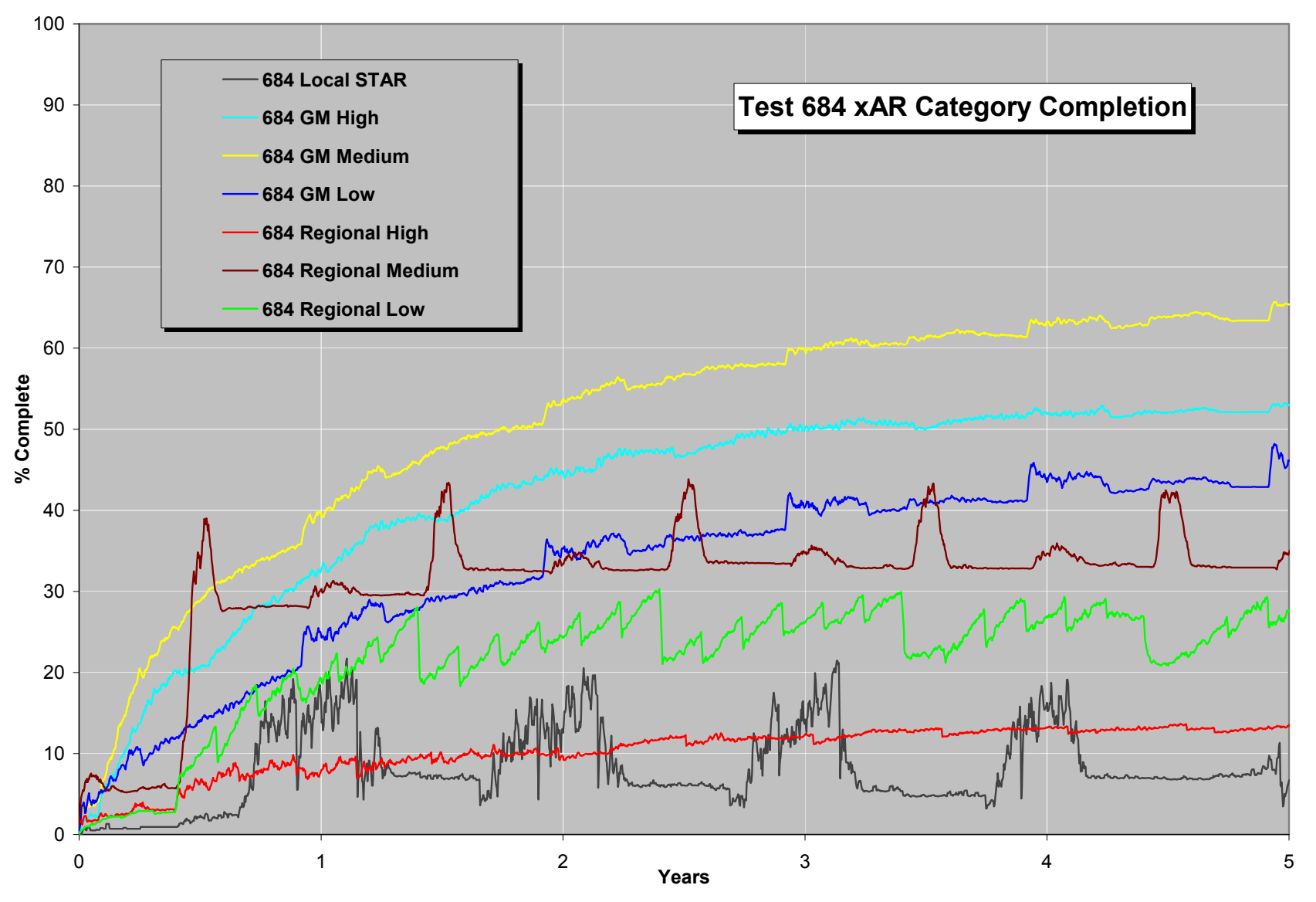
AMS Examples
Acquisition Requests



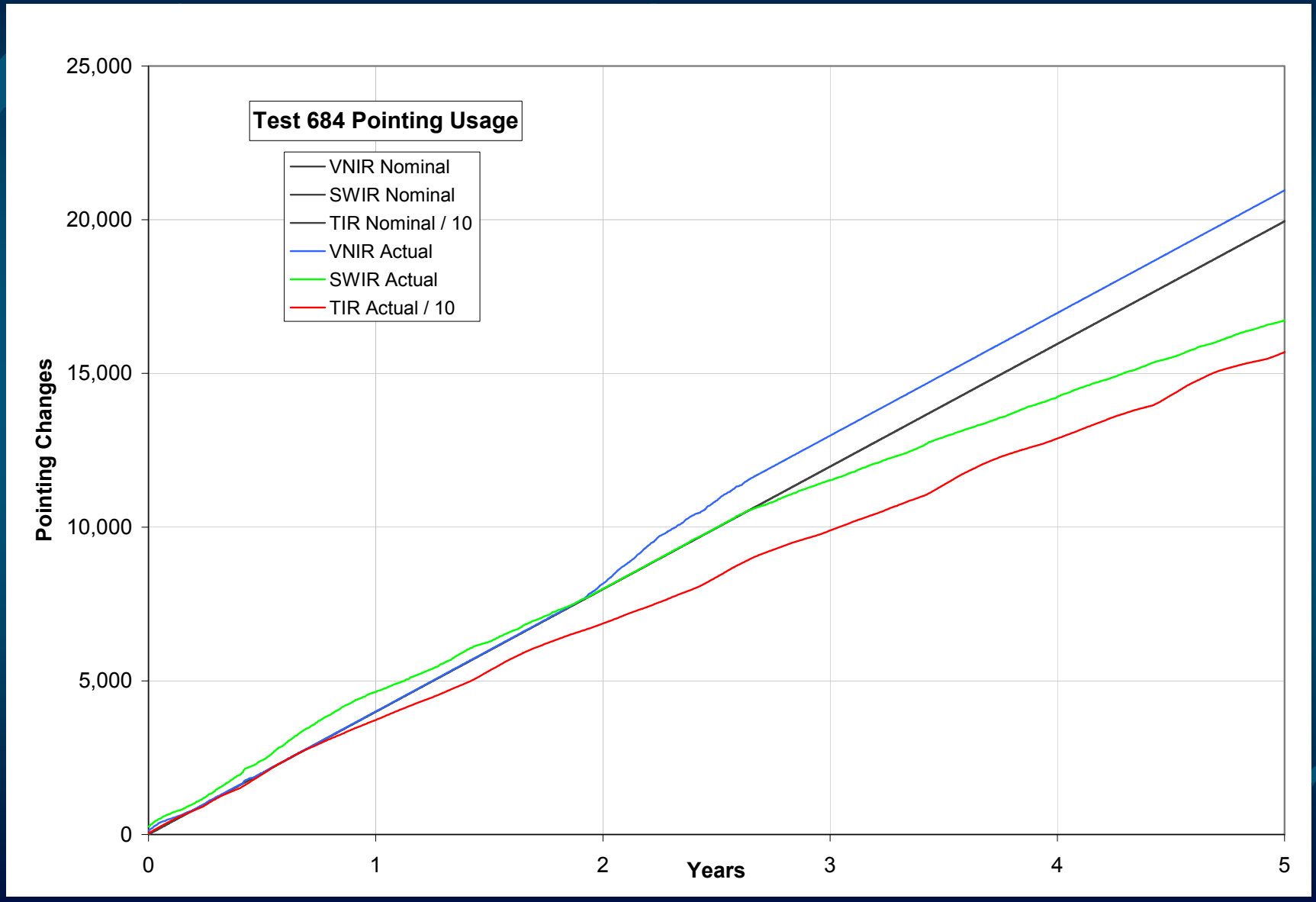
AMS Examples
Number of Times Areas Observed



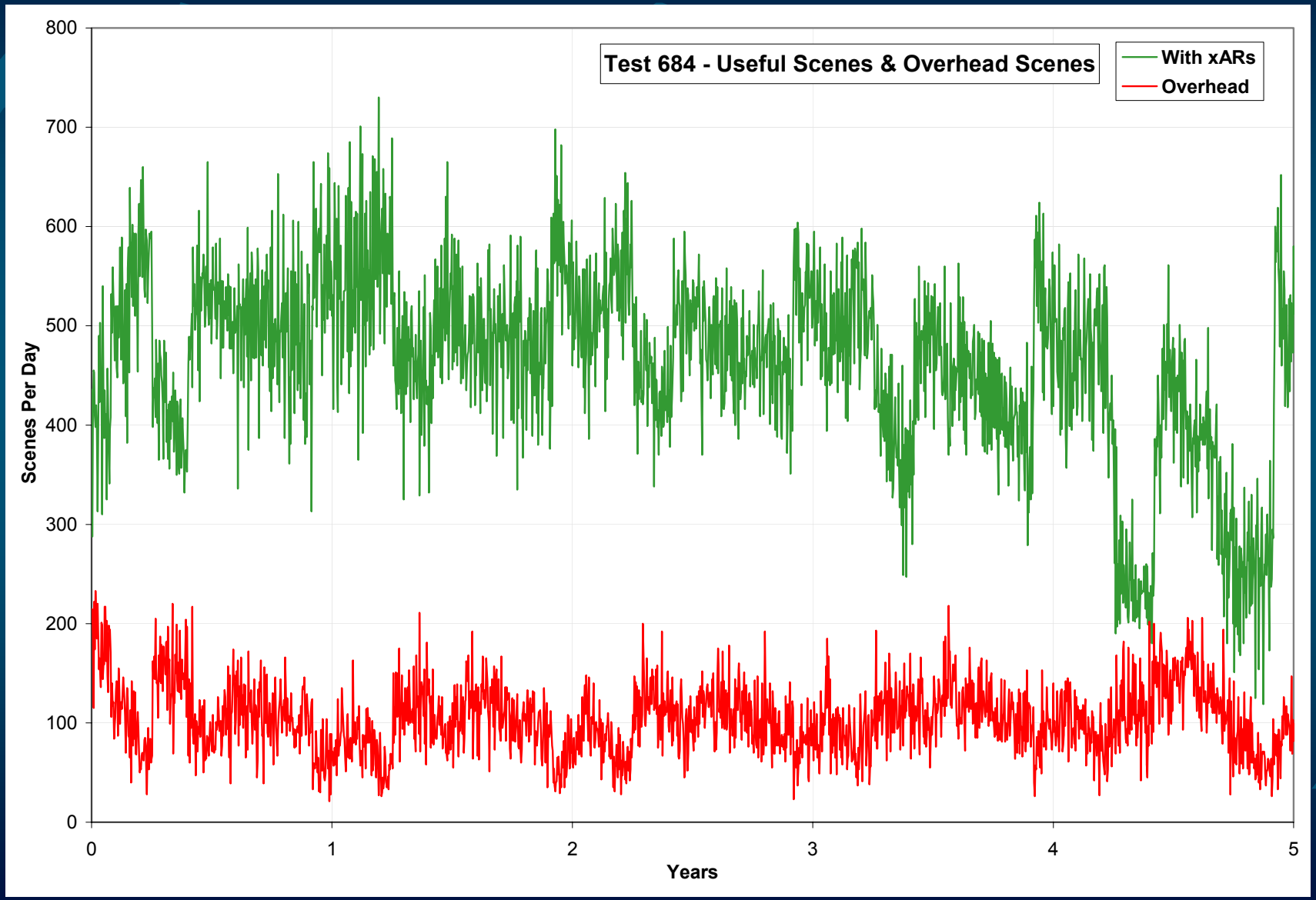
AMS Examples
Completion of Acquisition Request Categories



AMS Examples
Use of Pointing Resource vs. Time



AMS Examples
Observed Data vs. Valuable Data



Potential Future Applications

- Other Earth-observing missions
- Planetary missions
  - Mars Reconnaissance Orbiter
- Coordinated and distributed observations
  - Multiple spacecraft or sensors
  - Multiple dynamic targets